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National Eutrophication Survey, Las Vegas, Nev

Prepared for

Environmental Monitoring and Support Lab, Las Vegas, Nev

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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REPORT
ON
DEGRAY RESERVOIR
CLARK AND HOT SPRING COUNTIES
ARKANSAS
EPA REGION VI
WORKING PAPER NO. 485

WITH THE COOPERATION OF THE
ARKANSAS DEPARTMENT OF POLLUTION
CONTROL AND ECOLOGY
AND THE
ARKANSAS NATIONAL GUARD
JANUARY, 1977

REPORT ON DEGRAY RESERVOIR

CLARK AND HOT SPRING COUNTIES, ARKANSAS

EPA REGION VI

by

National Eutrophication Survey

Water and Land Monitoring Branch
Monitoring Applications Laboratory
Environmental Monitoring & Support Laboratory
Las Vegas, Nevada

and

Eutrophication Survey Branch
Corvallis Environmental Research Laboratory
Corvallis, Oregon

Working Paper No. 485

OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY

January 1977

CONTENTS

	Page
Foreword	ii
List of Arkansas Study Lakes	iv
Lake and Drainage Area Map	v
Sections:	
I. Conclusions	1
II. Lake and Drainage Basin Characteristics	4
III. Lake Water Quality Summary	6
IV. Nutrient Loadings	12
V. Literature Reviewed	18
VI. Appendices	19

FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point source discharge reduction and nonpoint source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by the U.S. Environmental Protection Agency and to augment plans implementation by the states.

ACKNOWLEDGMENTS

The staff of the National Eutrophication Survey (Office of Research and Development, U.S. Environmental Protection Agency) expresses sincere appreciation to the Arkansas Department of Pollution Control and Ecology for professional involvement, to the Arkansas National Guard for conducting the tributary sampling phase of the survey, and to those Arkansas wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Water Division of the Arkansas Department of Pollution Control and Ecology provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports and provided critiques most useful in the preparation of this Working Paper series.

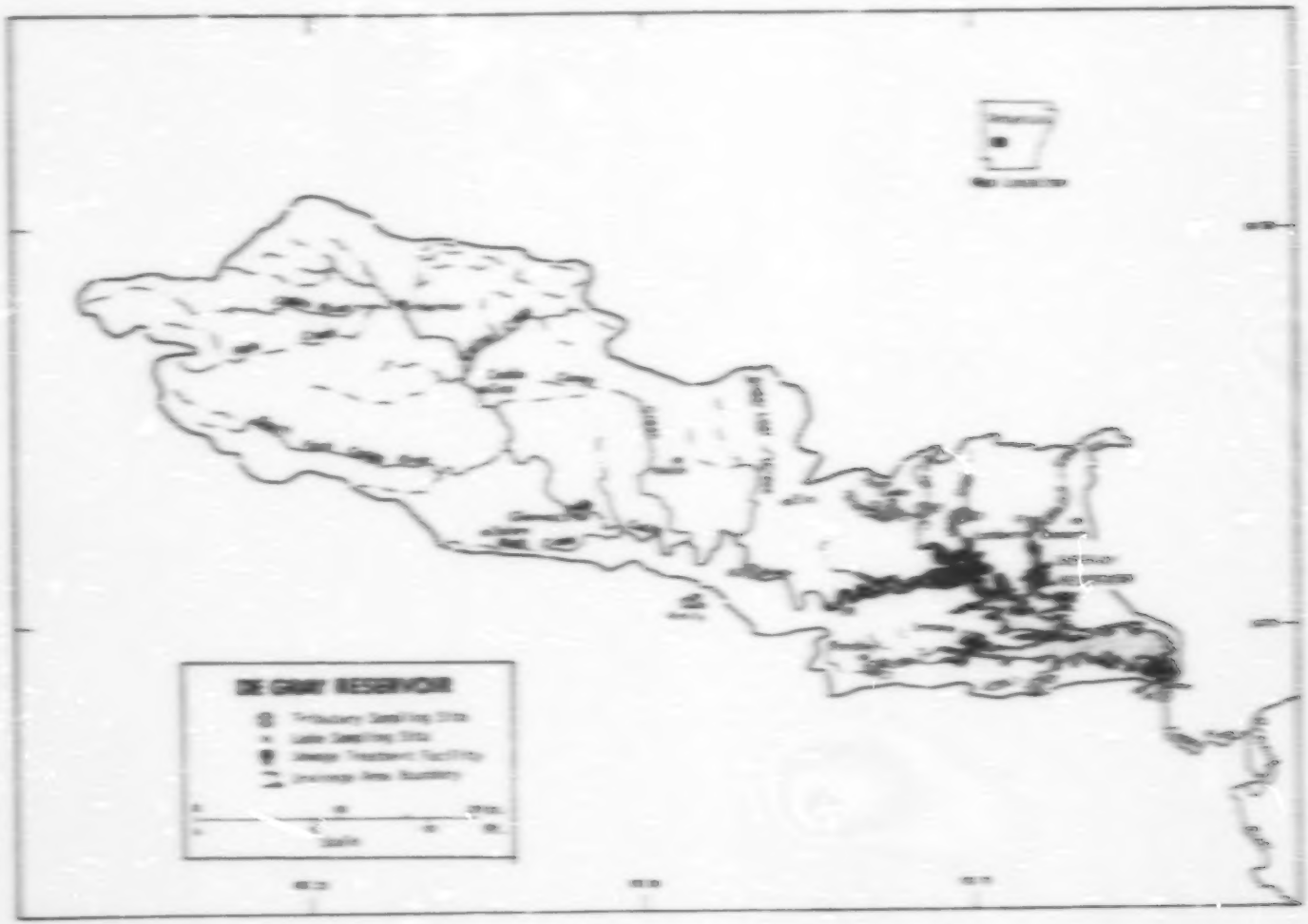
Major General Thomas C. Armstrong, the Adjutant General of Arkansas, and Project Officer Colonel Lavaun M. James, who directed the volunteer efforts of the Arkansas National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF ARKANSAS

LAKE NAME	COUNTY
Beaver	Benton, Carroll, Washington
Blackfish	Crittenden, St. Francis
Blue Mountain	Logan, Yell
Bull Shoals	Baxter, Boone, Marion (Taney, Ozark in MO)
Catherine	Garland, Hot Spring
Chicot	Chicot
DeGray	Clark, Hot Spring
Erling	Lafayette
Grand	Chicot
Greer's Ferry	Van Buren, Cleburne
Hamilton	Garland
Millwood	Hempstead, Howard, Little River, Sevier
Nimrod	Perry, Yell
Norfork	Baxter, Fulton (Ozark in MO)
Ouachita	Garland, Montgomery
Table Rock	Boone, Carroll (Barry, Taney in MO)



REPORT ON DEGRAY RESERVOIR, ARKANSAS
STORET NO. 0507

I. CONCLUSIONS

A. Trophic Condition:

Based upon field observations and Survey data DeGray Reservoir is considered mesotrophic. Chlorophyll a values ranged from a low of 1.4 µg/l in the spring to a high of 29.0 µg/l in the summer with a mean of 10.1 µg/l. The mean Secchi disc reading for the lake was 205 cm (81 inches). Of the 13 Arkansas lakes sampled in 1974, 11 had greater median total phosphorus and median inorganic nitrogen values, and 13 had greater median dissolved orthophosphorus levels than DeGray Reservoir.

Survey limnologists did not observe any nuisance conditions during their visits to the lake.

B. Rate-Limiting Nutrient:

Algal assay results indicate that DeGray Reservoir is limited by available phosphorus. Spikes with phosphorus alone or nitrogen and phosphorus simultaneously resulted in increased assay yields. The addition of nitrogen alone did not produce a growth response. The ratios of total inorganic nitrogen to orthophosphorus (N/P) in the lake data suggest nitrogen limitation in the spring and phosphorus limitation in the summer and fall.

*See Appendix E

C. Nutrient Controllability:

1. Point sources -

The mean annual phosphorus load from point sources was estimated to be 10.6% of the total load reaching DeGray Reservoir. The city of Glenwood contributed this entire point source load.

The present phosphorus loading of 0.22 g $P/m^2/yr$ is less than that proposed by Vollenweider (1975) as an oligotraphic rate (see Section IV-F). However, summer chlorophyll a values in the lake (18.9 - 29.0 µg/l) indicate a much higher biological response to existing nutrient levels than would ordinarily be expected. In light of this demonstrated increase in summer lake productivity, it would be desirable to reduce phosphorus contributions from the city of Glenwood to the greatest practicable extent in order to protect the existing high water quality of DeGray Reservoir.

Loading calculations based upon available nutrient concentrations yield an apparent net export of nitrogen from the impoundment, indicating that sampling was not adequate to depict actual loading and/or export rates of that nutrient.

8. Nonpoint sources -

Nonpoint sources contributed 88.3% of the phosphorus load reaching DeGray Reservoir. Measured tributaries accounted for 64.8% of the total phosphorus load and the ungaged tributaries were estimated to contribute 15.1%.

The nonpoint phosphorus exports (Section IV-D) of the Caddo River, Whitener Creek, and Big Hill Creek are quite comparable to the exports of the unimpacted tributaries of nearby Ouachita, Hamilton, and Catherine Lakes (mean of 10 kg $P/km^2/yr$, range of 6 to 19 kg $P/km^2/yr$).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS

Lake and drainage basin characteristics are itemized below. Lake morphometry was provided by the Arkansas Department of Pollution Control and Ecology. Tributary flow data were provided by the Arkansas District Office of the U.S. Geological Survey (USGS). Outlet drainage area includes the lake surface area. Mean hydraulic retention time was obtained by dividing the lake volume by the mean flow of the outlet. Precipitation values are estimated by methods as outlined in National Eutrophication Survey (NES) Working Paper No. 175. A table of metric/English conversions is included as Appendix A.

A. Lake Morphometry:

1. Surface area: 54.23 km^2.
2. Mean depth: 14.9 meters.
3. Maximum depth: 60.3 meters.
4. Volume: 807.566 x 10^6 m^3.
5. Mean hydraulic retention time: 477 days.

B. Tributary and Outlet:
(See Appendix B for flow data)

1. Tributaries -

Name	Drainage area(km²)	Mean flow (m³/sec)
A-2 Caddo River	704.8	13.88
D-1 Whitener Creek	19.7	0.26
F-1 Big Hill Creek	18.1	0.27
Minor tributaries and immediate drainage -	296.5	5.33
Totals	1,119.1	19.74
2. Outlet - A-1 Caddo River	1,173.3	19.56

C. Precipitation:

1. Year of sampling: 169.5 cm.
2. Mean annual: 133.5 cm.

III. LAKE WATER QUALITY SUMMARY

DeGray Reservoir was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from six stations on the lake (Station 06 was not sampled the second round) and from a number of depths at each station (see map, page v). During each visit, depth-integrated samples were collected from each station for chlorophyll a analysis and phytoplankton identification and enumeration. During the first and last visits, 18.9-liter depth-integrated samples were composited for algal assays. Maximum depths sampled were 50.6 meters at Station 01, 38.1 meters at Station 02, 9.8 meters at Station 03, 14.6 meters at Station 04, 12.2 meters at Station 05, and 9.1 meters at Station 06. For a more detailed explanation of NES methods, see NES Working Paper No. 175.

The results obtained are presented in full in Appendix C and are summarized in III-A for waters at the surface and at the maximum depth for each site. Results of the phytoplankton counts and chlorophyll a determinations are included in III-B. Results of the limiting nutrient study are presented in III-C.

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PHYSICAL AND CHEMICAL CHARACTERISTICS

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B. Biological Characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
03/25/74	1. Ankistrodesmus	287
	2. Dynobryon	273
	3. Melosira	191
	4. Asterionella	159
	5. Tabellaria	159
	Other genera	606
	Total	1,675
06/03,05/74	1. Tabellaria	6,083
	2. Melosira	1,102
	3. Chroomonas	634
	4. Aphanizomenon	317
	5. Oscillatoria	317
	Other genera	663
	Total	9,196
10/16/74	1. Nitzschia	238
	2. Ankistrodesmus	214
	3. Chroomonas	214
	4. Mougeotia	167
	5. Raphidiopsis	143
	Other genera	1,002
	Total	1,978

F. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (ug/l)
03/25/74	01	2.0
	02	2.5
	03	3.1
	04	2.6
	05	3.0
	06	1.4
06/03/74	01	23.3
	02	29.6
	03	16.9
	04	25.3
	05	22.1
	06	****
10/16/74	01	4.4
	02	3.6
	03	3.8
	04	6.9
	05	6.2
	06	11.1

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. 03/25/74 - Stations 01-04

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.010	0.161	0.1
0.05 P	0.060	0.161	3.6
0.05 P + 1.0 N	0.060	1.161	22.6
1.00 N	0.010	1.161	0.1

b. 03/25/74 - Stations 05-06

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.005	0.000	0.1
0.05 P	0.055	0.000	3.1
0.05 P + 1.0 N	0.055	1.000	24.0
1.00 N	0.005	1.000	0.1

c. 10/16/74 - Stations 01-03

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic P Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.007	0.155	0.3
0.05 P	0.057	0.155	1.1
0.05 P + 1.0 N	0.057	1.155	3.6
1.00 N	0.007	1.155	0.3

d. 10/16/74 - Stations 04-06

Spike(mg/l)	Ortho P Conc.(mg/l)	Inorganic N Conc.(mg/l)	Maximum Yield (mg/l-dry wt.)
Control	0.010	0.113	0.4
0.05 P	0.060	0.113	2.4
0.05 P + 1.0 N	0.060	1.113	10.6
1.00 N	0.010	1.113	0.4

B. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential for primary production was low on DeGray Reservoir during the spring and fall sampling periods. The lake was phosphorus limited at those times as indicated by the increased yield of the test alga in response to an addition of orthophosphorus. Spikes with phosphorus and nitrogen simultaneously resulted in maximum yields. Spikes with nitrogen alone did not produce a response beyond the control yield.

The mean total available inorganic nitrogen to orthophosphorus ratio in the spring lake data was 11/1, suggesting primary limitation by nitrogen. The ratios for the summer and fall data were 49/1 and 38/1, respectively, suggesting phosphorus limitation at those times (an N/P ratio of 14/1 or greater generally reflects phosphorus limitation).

IV. NUTRIENT LOADINGS
(See Appendix D for data)

For the determination of nutrient loadings, the Arkansas National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page 9), except for the high runoff months of March and April when two samples were collected. Sampling was begun in June 1974, and was completed in May 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Arkansas District Office of the USGS for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a USGS computer program for calculating stream loadings. Nutrient loads indicated for tributaries are those measured minus known point source loads, if any.

Nutrient loadings for unsampled "minor tributaries and immediate drainage" ("ZZ" of USGS) were estimated by using the mean annual nutrient loads, in kg/km^2/yr, in Whitener Creek and Big Hill Creek at Stations D-1 and F-1, and multiplying the means by the ZZ area in km^2.

Nutrient loads for the city of Glenwood wastewater treatment plant were estimated at 1.134 kg P and 3.401 kg N/Capita/yr.

A. Waste Sources:

1. Known municipal -

Name	Population Served*	Treatment*	Mean Flow ($m^3/d \times 10^3$)	Receiving Water
Glenwood	1,212	Stabilization pond	0.459**	Caudo River

2. Known industrial - None

*U.S. EPA, 1971.
**Estimated at 0.3785 m^3/capita/day.

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/yr	% of total
a. Tributaries (nonpoint load) -		
A-2 Caddo River	7,305	62.0
D-1 Whitener Creek	100	0.9
F-1 Big Hill Creek	120	1.0
b. Minor tributaries and immediate drainage (nonpoint load) -	1,780	15.1
c. Known municipal STP's -		
Glenwood	1,375	11.7
d. Septic tanks* -	30	0.3
e. Known industrial - None		
f. Direct precipitation** -	950	8.1
Total	11,750	100.0
2. Output - A-1 Caddo River	10,270	
3. Net annual P accumulation -	1,480	

*Estimate based on 24 lakeside residences, 12 camps, and 1 park.
**Estimated (see NES Working Paper No. 175).

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (nonpoint load) -		
A-3 Caddo River	100,645	52.0
D-1 Whitener Creek	1,330	0.7
F-1 Big Hill Creek	1,920	1.0
b. Minor tributaries and immediate drainage (nonpoint load) -	25,795	13.3
c. Known municipal STP's -		
Glenwood	4,120	2.1
d. Septic tanks* -	1,135	0.6
e. Known industrial - None		
f. Direct precipitation** -	58,545	30.3
Total	193,390	100.0
2. Output - A-1 Caddo River	268,460	
3. Net annual N export*** -	75,070	

*Estimate based on 24 lakeside residences, 12 camps, and 1 park.
**Estimated (see NES Working Paper No. 175).
***Export probably due to unknown sources and/or sampling error.

D. Mean Annual Nonpoint Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Caddo River	9	128
Whitener Creek	5	68
Big Hill Creek	7	106

E. Mean Nutrient Concentrations in Ungaged Streams:

Tributary	Mean Total P (mg/l)	Mean Total N (mg/l)
B-1 Long Creek	0.022	0.230
C-1 Brushy Creek	0.020	0.414
E-1 Philippi Creek	0.015	0.364
G-1 Point Cedar Creek	0.022	0.245

Nutrient concentrations for the above tributaries are consistent with those found for the gaged tributaries entering DeGray Reservoir.

F. Yearly Loadings:

In the following table, the existing phosphorus annual loading is compared to the relationship proposed by Vollenweider (1975). Essentially, his eutrophic loading is that at which the receiving waters would become eutrophic or remain eutrophic; his oligotrophic loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between eutrophic and oligotrophic.

Note that Vollenweider's model may not apply to lakes with short hydraulic retention times or in which light penetration is severely restricted by high concentrations of suspended solids in the surface waters.

	Total Yearly Phosphorus Loading ($g/m^2/yr$)
Estimated loading for DeGray Reservoir	0.22
Vollenweider's eutrophic loading	0.64
Vollenweider's oligotrophic loading	0.32

V. LITERATURE REVIEWED

U.S. Environmental Protection Agency. 1971. A 1968 Inventory of Municipal Waste Facilities. EPA Publication No. OWP-1, Vol. 6. U.S. Government Printing Office, Washington, D.C.

U.S. Environmental Protection Agency. 1975. National Eutrophication Survey Methods 1973-1976. Working Paper No. 175. National Environmental Research Center, Las Vegas, Nevada, and Pacific Northwest Environmental Research Laboratory, Corvallis, Oregon.

Vollenweider, R. A. 1975. Input-Output Models With Special Reference to the Phosphorus Loading Concept in Limnology. Schweiz. Z. Hydrol. 37:53-84.

VI. APPENDICES

APPENDIX A
CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 0.107 x 10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX B
TRIBUTARY FLOW DATA

APPENDIX C
PHYSICAL AND CHEMICAL DATA

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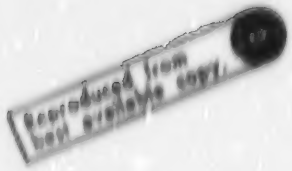
APPENDIX D

TRIBUTARY DATA



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APPENDIX E

PARAMETRIC RANKINGS OF LAKES SAMPLED BY NES IN 1974

STATE OF ARKANSAS